Strategies to Protect the Health of Deployed U.S. Forces

Force Protection and Decontamination

Michael A. Wartell, Michael T. Kleinman,
Beverly M. Huey, and Laura M. Duffy, *Editors*

Strategies to Protect the Health of Deployed U.S. Forces:
Physical Protection and Decontamination

Division of Military Science and Technology
Commission on Engineering and Technical Systems

National Research Council

NATIONAL ACADEMY PRESS
Washington, D.C.

NOTICE: The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The authors responsible for the report were chosen for their special competencies and with regard for appropriate balance.

This is a report of work supported by Contract DASW01-97-C-0078 between the National Academy of Sciences and the Department of Defense. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the view of the organizations or agencies that provided support for the project.

International Standard Book Number 0-309-06793-6

Limited copies are available from:

Board on Army Science and Technology
National Research Council,
2101 Constitution Avenue, N.W.
Washington, D.C. 20418
(202) 334-3118

Additional copies are available from:

National Academy Press
2101 Constitution Ave., N.W.
Box 285
Washington, D.C. 20055
800-624-6242/202-334-3313
(in the Washington metropolitan area)

Printed in the United States of America.

THE NATIONAL ACADEMIES

National Academy of Sciences
National Academy of Engineering
Institute of Medicine
National Research Council

The **National Academy of Sciences** is a private, nonprofit, self-perpetuating society of distinguished scholars engaged in scientific and engineering research, dedicated to the furtherance of science and technology and to their use for the general welfare. Upon the authority of the charter granted to it by the Congress in 1863, the Academy has a mandate that requires it to advise the federal government on scientific and technical matters. Dr. Bruce M. Alberts is president of the National Academy of Sciences.

The **National Academy of Engineering** was established in 1964, under the charter of the National Academy of Sciences, as a parallel organization of outstanding engineers. It is autonomous in its administration and in the selection of its members, sharing with the National Academy of Sciences the responsibility for advising the federal government. The National Academy of Engineering also sponsors engineering programs aimed at meeting national needs, encourages education and research, and recognizes the superior achievements of engineers. Dr. William A. Wulf is president of the National Academy of Engineering.

The **Institute of Medicine** was established in 1970 by the National Academy of Sciences to secure the services of eminent members of appropriate professions in the examination of policy matters pertaining to the health of the public. The Institute acts under the responsibility given to the National Academy of Sciences by its congressional charter to be an adviser to the federal government and, upon its own initiative, to identify issues of medical care, research, and education. Dr. Kenneth I. Shine is president of the Institute of Medicine.

The **National Research Council** was organized by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purposes of furthering knowledge and advising the federal government. Functioning in accordance with general policies determined by the Academy, the Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in providing services to the government, the public, and the scientific and engineering communities. The Council is administered jointly by both Academies and the Institute of Medicine. Dr. Bruce M. Alberts and Dr. William A. Wulf are chairman and vice chairman, respectively, of the National Research Council.

STRATEGIES TO PROTECT THE HEALTH OF DEPLOYED U.S. FORCES: FORCE PROTECTION AND DECONTAMINATION

Principal Investigators

MICHAEL T. KLEINMAN, University of California, Irvine
MICHAEL A. WARTELL, Indiana University-Purdue University Fort Wayne

Advisory Panel

WYETT H. COLCLASURE II, Environmental Technologies Group, Inc., Baltimore, Maryland
STEPHEN HILL, Global Analytics, Inc., Orange, Virginia
SIDNEY A. KATZ, Rutgers University, Camden, New Jersey
FRANK K. KO, Drexel University, Philadelphia, Pennsylvania
HOWARD IRA MAIBACH, University of California, San Francisco
NAJMEDIN MESHKATI, University of Southern California, Los Angeles

Board on Army Science and Technology Liaison

JOSEPH J. VERVIER, ENSCO, Inc., Melbourne, Florida

Staff

BRUCE A. BRAUN, Director, Division of Military Science and Technology
BEVERLY M. HUEY, Study Director
LAURA M. DUFFY, Research Associate
PAMELA A. LEWIS, Senior Project Assistant
ANDRE MORROW, Senior Project Assistant

Department of Defense Liaisons

MICHAEL KILPATRICK, Office of the Special Assistant for Gulf War Illnesses, Falls Church, Virginia
FRANCIS L. O'DONNELL, Office of the Special Assistant for Gulf War Illnesses, Falls Church, Virginia

BOARD ON ARMY SCIENCE AND TECHNOLOGY

Staff

BRUCE A. BRAUN. Director
MICHAEL A. CLARKE, Associate Director
MARGO L. FRANCESCO, Staff Associate
CHRIS JONES, Financial Associate
DEANNA SPARGER, Senior Project Assistant

Preface

Chemical and biological (CB) warfare has been the subject of numerous studies supported by a wide spectrum of sponsoring groups, ranging from the military to private sector foundations. Given how much has already been said on the subject, one might conclude that little remains on which to comment. However, the subject is complex and controversial enough that with each new hostile military encounter, with each potential new threat, with each report of a possible terrorist action using CB agents, our defensive preparedness comes under new scrutiny.

The military experience in the Gulf War, while overwhelmingly positive by almost any measure, raised some concerns. One obvious uncertainty was that there might be a causal relationship between the presence of CB agents in theater and the symptoms reported by returning military personnel, later named the "Gulf War Syndrome." Studies focused initially on whether personnel might have been exposed to low-level doses of chemical agents, and if this exposure could have resulted in the reported symptoms. More recent studies have been expanded to cover the whole range of CB defense, from medical issues to materiel development to doctrine and training.

Responding to the need for an evaluation of the military's ability to prosecute missions in CB environments, the Department of Defense Office of the Special Assistant for Gulf War Illnesses, through the National Academies, sponsored a study of strategies to protect the health of deployed U.S. forces, focused on CB defense. The first part of this three-year study was divided into four parallel studies (1) to develop an analytical framework for assessing the risks to deployed forces; (2) to review and

evaluate technologies and methods for detection and tracking exposures to those risks; (3) to review and evaluate physical protection and decontamination; and (4) to review and evaluate medical protection, health consequences and treatment, and medical record keeping. Now, at the end of the second year of the study, each group is providing a report to DoD and the public on its findings and recommendations in these areas. These four documents will be used as a basis for a new National Academies consensus committee that will prepare a synthesis report for DoD in the third year of the project. The consensus committee will consider, not only the topics covered in the four two-year studies, but also overarching issues relevant to its broader charge.

This report responds to the third of the first four studies, physical protection and decontamination. The task, which is more fully described in the first chapter, includes (1) an assessment of DoD's approaches and technologies for physical protection—both individual and collective—against CB warfare agents and decontamination of personnel and equipment, and (2) an assessment of DoD's current policies, doctrine, and training. The issues of space, budget, and staffing allocations for these programs, although extremely important, are beyond the scope of this report. Unlike most National Academies studies, two principal investigators conducted this study, with the assistance and guidance of an advisory panel. The expertise of this advisory panel covered various topics addressed by the study.

During the data-gathering phase, we received extensive briefings, visited various facilities, consulted with numerous experts, solicited commissioned papers on specialized topics, attended many related national conferences and symposia, and reviewed other material provided by DoD and from the open literature. We also held one workshop to gather additional information on focussed topics. We are indebted to the organizations and individuals that gave freely of their time and talents to this project. A special note of thanks to the individuals, listed by name, appears in Appendix F of this report. Given the countless individuals who shared their expertise with us, there is no doubt the list is incomplete; and we apologize for the oversights.

In responding to our Statement of Task, we attempted to cover each aspect of the requested information, adding introductory and historical information. No single study, however, can do justice to the entire breadth of topics included in our study charge. Therefore, we decided to focus on issues on which we believed we could provide especially helpful advice to the military.

During the course of the study, we were struck by several aspects of the CB defense community: (1) their dedication to their professions, in general, and to CB protection, in particular; (2) the extent to which

decades-old threat information continues to influence current requirements and considerations; (3) the willingness of policy makers to accept "worst case" assessments against which to develop programs, as opposed to developing more valid benchmarks based on more up-to-date information; (4) the continuing need for basic science information on the chemical, physical, and toxicological properties of CB agents to facilitate the development of modeling and simulations; (5) the need for more and better uses of modeling and simulations; and (6) the contrast between the high quality doctrine and training approaches available and inconsistent CB training across services and across units.

We wish to emphasize that the CB defense community is competent, caring, and dedicated. Although we suggest areas for improvement in this report, we retain a strongly positive overall impression of the work of the CB community.

The individuals who reviewed the draft report were especially important to the construction of the final report. They provided thoughtful and constructive comments that significantly enhanced the quality of the final report. Finally, we gratefully acknowledge the work and support of Beverly Huey, the National Academies study director for this project. Her dedication, intelligence, and flexibility were invaluable and are deeply appreciated. We also thank Laura Duffy, the research associate, for her efforts in acquiring and organizing data that were central to our analyses.

Michael T. Kleinman
Michael A. Wartell
Principal Investigators

Strategies to Protect the Health of Deployed U.S. Forces:
Physical Protection and Decontamination

Acknowledgments

We are appreciative of the cooperation we received from the many individuals and organizations who provided valuable information and guidance to us in the course of our work. First, we extend our sincere thanks to the members of the advisory panel who provided assistance and guidance during the information gathering process, gave thought-provoking presentations in their respective areas of expertise, participated in briefings from various organizations, and provided thoughtful comments on the initial drafts of this report. We are also indebted to those individuals who prepared commissioned papers for our use: William Hinds, who wrote a paper on respiratory protection; Sidney Katz on air contaminant removal; Frank Ko on textiles and garments for chemical and biological protection; Howard I. Maibach and Hongbo Zhai on barrier creams, percutaneous absorption, and skin decontamination techniques; and Maher Todios on decontamination.

We are grateful for the guidance and support from others at the National Academies, including Joseph Cassells and Suzanne Woolsey, who assisted in the coordination of the four separate study efforts as they were simultaneously being conducted; Bruce Braun, who assisted in scoping the study, nurtured it throughout its execution and provided ongoing oversight; and Douglas Bauer and Dennis Chamot, who adeptly dealt with stumbling blocks when they occurred in the process and provided thoughtful insights throughout the course of the study. We also appreciate the work of Pamela Lewis who provided administrative assistance in preparing this document for review and publication, and Carol Arenberg, who edited this document, enhancing its clarity. Finally, we are indebted

to numerous other NRC staff for their individual contributions: Mike Clarke, associate division director; Margo Francesco, staff associate; Delphine Glaze, Jacqueline Campbell-Johnson, and Andre Morrow, senior project assistants; and Alvera Wilson, financial associate.

Without the extensive contributions and thought-provoking comments so freely given by so many individuals throughout the course of this study, we could not have completed the task set before us. We would like to acknowledge those individuals who provided briefings, arranged site visits to their organizations, gave presentations at the workshop, supplied invaluable information and reports critical to our charge, answered our searching questions very honestly, and assisted us in contacting other sources who could provide additional information and documentation not easily accessible. There is no doubt the list is incomplete, and we apologize for any oversights (see Appendix F).

This report has also been reviewed by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the National Research Council's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the authors and the National Research Council in making the published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The content of the review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following individuals for their participation in the review of this report:

Robert E. Boyle, Department of the Army (retired)
Gerald T. Dinneen, Honeywell, Inc. (retired)
Stephen W. Drew, Merck & Co., Inc.
Valerie J. Gawron, Veridian Engineering
Trevor J. Little, North Carolina State University
John Nelson, NBC Defense Systems (retired)
Donald F. Petersen, Department of Defense Health Effects Programs (retired)
Ellen Raber, Lawrence Livermore National Laboratory
William G. Reifenrath, Reifenrath Consulting & Research
Bruce O. Stuart, Schering-Plough Research Institute

While all of the advisors and reviewers listed above have provided many constructive comments and suggestions, responsibility for the final content of this report rests solely with the authoring principal investigators and the National Research Council.

Contents

Tables, Figures, and Box

TABLES

FIGURES

BOX

Abbreviations and Acronyms

ABBREVIATIONS

2D	two dimensional
3D	three dimensional
cfm	cubic foot per minute
CG	phosgene
Cl	chlorine
CK	cyanogen chloride
Ct	concentration × time
CX	phosgene oxime
D_{10}	the dose level required to reduce the sample population by a factor of 10
DS2	decontaminating solution number 2
DS2P	propylene glycol monomethyl ether
ECt_{50}	the *Ct* dose that causes a defined effect (e.g., edema or death) in 50 percent of a given population
GA	tabun
GB	sarin
GD	soman
g/den	gram per denier

H	Levinstein mustard
H2S	hydrogen sulfide
HD	distilled mustard
HL	mustard-lewisite mixture
HN	nitrogen mustard
ICt_{50}	the *Ct* dose that incapacitates 50 percent of a given population
ID_{50}	the dose that incapacitates 50 percent of a given population
L	Lewisite
lpm	liters per minute
MeV	million electron volts
m^2/g	square meter per gram
$mg \times min/m^3$	milligram times minute per cubed meter
mm	millimeter
nm	nanometers
NO_x	nitrogen oxides
ppb	parts per billion
Ω-kg/m^2	ohm kilogram per square meter

ACRONYMS

AERP	aircrew eye/respiratory protection
ALERT	attack and launch early reporting to theater
ASTM	American Society for Testing and Materials
AUIB	aircrew uniform integrated battlefield
BDO	battle dress overgarment
BDU	battle dress uniform
BWC	Biological and Toxic Weapons Convention
CB	chemical and/or biological
CBIRF	Chemical Biological Incident Response Force
CINC	commander-in-chief
CONUS	continental United States
CPE	collective protection equipment
CPU	chemical protective undergarment

CWC	Chemical Weapons Convention
DARPA	Defense Advanced Research Projects Agency
DATSD (CP/CBD)	Deputy Assistant to the Secretary of Defense for Counter-proliferation and Chemical/Biological Defense
DEPMEDS	deployable medical system
DoD	U.S. Department of Defense
DMMP	dimethyl methylphosphate
DPD	dermatopharmacodynamic
DPK	dermatopharmacokinetic
ERDEC	Edgewood Research, Development, and Engineering Center (now known as the Chemical-Biological Center of Excellence of the Soldier and Biological Chemical Command)
FF	fit factor
FM	field manual
FOC	functional operational capability
FR	flame resistance
FY	fiscal year
ICBPG	improved chemical and biological protective glove
IOM	Institute of Medicine
JCS	Joint Chiefs of Staff
JPO-BD	Joint Program Office for Biological Defense
JSAPE	joint service aircrew protective ensemble
JSAM	joint service aircrew mask
JSGPM	joint service general purpose mask
JSIG	Joint Service Integration Group
JSLIST	joint service lightweight integrated suit technology
JSMG	Joint Service Materiel Group
LCBPG	lightweight chemical/biological protective garment
LRC	lesser regional conflicts
LSC	liquid scintillation counting
MAG	military air guideline
MCBAT	Medical Chemical-Biological Advisory Team
MIST	Man-in-Simulant Test (program)

MLRS	multiple launch rocket system
MNS	mission needs statement
MOPP	mission-oriented protective posture
MRC	major regional conflicts
MULO	multipurpose rain/snow/CB overboot
MURI	multidisciplinary university research initiative
NATO	North Atlantic Treaty Organization
NBC	nuclear, biological, chemical
NMR	nuclear magnetic resonance
OOTW	operations other than war
OPAA	organophosphorous acid anhydrolase
OPH	organophosphorous hydrolase
P3I	preplanned product improvement (program)
PF	protection factor
POM	program objective memorandum
PPE	personal protective equipment
PVC	polyvinyl chloride
R&D	research and development
RDA	research, development and acquisition
RDIC	resuscitation device individual chemical
RDT&E	research, development, test and evaluation
RSDL	reactive skin decontaminant lotion
SAW	surface acoustic wave
SBCCOM	Soldier and Biological Chemical Command
SCALP	suit, contamination avoidance, liquid protection
SLS	sodium lauryl sulfate
SMART-CB	special medical augmentation response team–chemical/biological
SMART-PM	special medical augmentation response team–preventative medicine
SRT	Specialty Response Team
STEPO	self-contained toxic environment protective outfit
TAP	toxicological agent protective
TEMPER	tent, expandable modular personnel
TG	technical guide
VHP	vapor of hydrogen peroxide
VPU	vapor protective undergarment

Strategies to Protect the Health of Deployed U.S. Forces